Introduction: Subjects with a normal hip joint need more than 120° of flexion in common activities of daily living (ADL). The reduction of range of motion (ROM) of a total hip replacement (THR) leads to frequent prosthetic impingement, subluxation and dislocation, especially for a patient with good hip movement. A larger oscillation angle and appropriate cup and neck positions make larger ROM until prosthetic impingement (theoretical ROM). The safe-zones for combined cup & neck anteversions that fulfill the severe criteria of ROM and their optimum combination were created.

Methods: The 4 ROM conditions: (1) Flexion (FL) more than 120°, (2) internal-rotation at 90° flexion (IR90) more than 45°, (3) external-rotation (ER) more than 40° and (4) extension (EXT) more than 30° were arbitrarily selected as the severe criteria of ROM without prosthetic impingement. The theoretical ROM is governed by 5 parameters: (1) oscillation angle: (θ) (so called technical ROM) (2) cup abduction: (α), (3) cup anterior opening: (rad), (4) the neck angle from the transverse plane (β), (5) neck anteversion from the coronal plane (b). FL, IR90, ER and EXT were calculated using these 5 parameters by the mathematical formulas previously developed (Yoshimine et al., 2002) (α) was fixed to 52° for 135° neck-stem angle. The 35°, 45°, 55° cup abductions and the 120°, 135° & 140° oscillation angles were selected. The maximum and minimum values of (βrad) that can fulfill all the severe criteria of ROM at a constant neck anteversion (b) were obtained, then the (βrad) was converted to the anatomic definition (cup anteversion: βanat) by the formula [βanat] = tan⁻¹(tan (βrad)sin (α)). So both (βanat) and (b) are the angle around the vertical axis. The max. & min. values of (βanat) obtained for (b) from 10° to 40° were plotted on the graph. The safe-zones of (βanat, b) that fulfill the severe criteria of ROM were created.

Result: There were the safe-zones for (θ) = 135°, 140° but almost no safe-zone for (θ) = 120° (Fig.2,3,4). In both (θ) = 135° and 140°, when the cup abduction changed from 35° to 45° then to 55°, the safe-zone of (βanat, b) sifted about 10° toward to a smaller (βanat) value and gradually increased in size (Fig. 2,3,4). In clinically relevant value of (b) from 10° to 30°, the average of the max. and min. (βanat) for each (b) was calculated (avβanat). The correlation of sum of (α) and (avβanat) ([α+βanat]) and (b) was analyzed by a linear regression for (θ) = 135°, 140°. This correlation was relatively independent on (θ). This revealed the linear correlation of (α+βanat) with (b) was shown by the formula [(α) + (βanat) + 0.80 (b) = 90.5]. In the case of THR with 135° neck stem angle, this formula can be used to estimate the acceptable neck anteversion when the cup position is decided. When the cup is positioned at 45° cup abduction (α) and 20° cup anterior opening (βrad), cup anteversion is 27° so the proper neck anteversion (b) will be 23°.

Discussion: The cup safe-zones are fully dependent on how the ROM criteria are defined. It is natural that the safe-zones for the severe criteria were smaller than the safe-zones for the moderate criteria we reported last time. The all safe-zones had a negative slope showing that neck anteversion should be reduced if the cup anteversion is increased. Cup abduction + anteversion ([α] + [βanat]) is correlated very well with neck anteversion (b) by the same formula ([α] + [βanat] + 0.80(b) = 90.5) even if (θ) was different when 135° neck stem angle and the severe criteria of ROM were used. However this combination does not guarantee that its cup and neck position is inside the safe-zone. It is clear that the larger the oscillation angle is, the larger the safe-zone is. There is almost no safe-zone for (θ) = 120°. Whether the cup and neck position is inside the safe-zone and can fulfill all the criteria of ROM is greatly influenced by the size of oscillation angle of THR used.

The use of THR with an oscillation angle (θ) of at least more than 135° is recommended, considering the difference of individual essential ROM, inaccuracy of pelvis position and the placement of cup and neck at operation, the variations of the position of the pelvis in the lying, sitting and standing posture and the change of pelvis position by aging.

**Fig. 1.** Left Hip (1) oscillation angle (θ), (2) cup abduction (α), (3) cup anteversion (βrad), (4) neck angle from transverse plane (α), (5) neck anteversion (b)

**Fig. 2.** Safe-zones of (βanat, b) for (θ) 120, 135, 145°, (α) = 35°.

**Fig. 3.** Safe-zones of (βanat, b) for (θ) 120, 135, 145°, (α) = 45°.

**Fig. 4.** Safe-zones of (βanat, b) for (θ) 120, 135, 145°, (α) = 55°.